REMARKS

Applicants have amended their claims in order to further clarify the definition of the present invention. Specifically, claims 6 and 37 have been amended as suggested by the Examiner in Item 1 on page 2 of the Office Action mailed December 3, 2001. The Examiner is thanked for these suggested amendments to claims 6 and 37, for overcoming the listed informalities. In light of these amendments to claims 6 and 37, it is respectfully submitted that the required corrections have been made; and that, moreover, claims 6 and 37 should now be allowed.

Applicants have amended each of claims 3, 30 and 36, the sole remaining claims that are rejected in the above-identified application, to recite a dielectric film of the semiconductor device, with this dielectric film positioned such that the neighboring film is between the dielectric film and the copper film interconnect (or between the copper film and the dielectric film).

Applicants respectfully request reconsideration and withdrawal of the finality of the Office Action mailed December 3, 2001. In this regard, Applicants respectfully direct attention to the rejection of claim 30, as unpatentable over the combined teachings of Hussein, et al. and the IBM Technical Disclosure Bulletin article, in this Office Action mailed December 3, 2001. In the previous Office Action, mailed July 6, 2001, claim 30 was rejected only as anticipated by the teachings of Schacham-Diamand, et al. See Item 4 on

pages 3 and 4 of the Office Action mailed July 6, 2001. Specifically, claim 30 was not rejected over the combined teachings of Hussein, et al. and the IBM Technical Disclosure Bulletin article, in the Office Action mailed July 6, 2001. Note Item 6 bridging pages 4 and 5 of the Office Action mailed July 6, 2001.

Moreover, note that in the Amendment filed November 6, 2001, in the present application, claim 30 was not amended in any manner whatsoever. Notwithstanding that claim 30 was not amended, in the Office Action mailed December 3, 2001, the Examiner issued a new rejection of claim 30, over references which were not applied against claim 30 in the Office Action mailed July 6, 2001. It is respectfully submitted that in view of this new rejection of claim 30, without any amendment of claim 30 whatsoever, the finality of the Office Action mailed December 3, 2001, is clearly improper. See Manual of Patent Examining Procedure (MPEP) 706.07(a). That is, since this section of the MPEP indicates that a second or subsequent action on the merits in any application will not be made final "if it includes a rejection, on newly cited art, of any claim not amended by Applicant in spite of the fact that other claims may have been amended to require newly cited art", clearly a new rejection of an unamended claim on previously cited art can not be made final. In view of the foregoing, reconsideration and withdrawal of the finality of the Office Action mailed December 3, 2001, and entry of the present amendments as a matter of right, are respectfully requested.

In any event, it is respectfully requested that the present amendments be entered. Noting, for example, the amendments to claims 6 and 37 as suggested by the Examiner, clearly these amendments do not raise any new issues, including any issue of new matter; materially limit any issues remaining in the application; and are timely in view of the objections to claims 6 and 37 being set forth for the first time in the Office Action mailed December 3, 2001. Moreover, noting, for example, Fig. 1, it is respectfully submitted that the amendments to claims 3, 30 and 36 do not raise any new issues, including any issue of new matter. Furthermore, these amendments to claims 3, 30 and 36 materially limit issues remaining in connection with the present invention; and based upon new contentions by the Examiner in the Office Action mailed December 3, 2001, are timely.

In view of all of the foregoing, it is respectfully submitted that Applicants have made the necessary showing under 37 CFR 1.116(b); and that, accordingly, entry of the present amendments is clearly timely, even if the finality of the Office Action mailed December 3, 2001, is not withdrawn.

Applicants thank the Examiner for indication of allowance of claims 1, 2, 4, 5, 9-20, 22-25, 27-29 and 31-35. Moreover, with the present amendments to claims 6 and 37, it is respectfully submitted that claims 6 and 37 should also be allowed.

As for the remaining claims, claims 3, 30 and 36, it is respectfully

submitted that the teachings of the references as applied by the Examiner in rejecting the claims considered by the Examiner in the Office Action mailed December 3, 2001, that is, U.S. Patent No. 6,020,266 to Hussein, et al., and the article in the IBM Technical Disclosure Bulletin, vol. 35, no. 1B (June 1992), entitled "Diffusion Barrier Between Copper and Silicon", would not have disclosed nor would have suggested the subject matter of the rejected claims as presently amended, under the provisions of 35 USC 103.

It is respectfully submitted that the references as applied by the Examiner in the Office Action mailed December 3, 2001 would have neither taught nor would have suggested the subject matter of claims 3, 30 and 36, including, inter alia, wherein the semiconductor device includes a copper film, or copper film interconnect, over a surface of the semiconductor substrate, and also has a dielectric film, and further has a neighboring film in contact with or adjacent the copper film (interconnect), and wherein the neighboring film is made of a specified material as in claims 3, 30 and 36 and the dielectric film is positioned such that the neighboring film is between the copper and the dielectric film. See claims 3, 30 and 36.

In addition, it is respectfully submitted that the applied references would have neither disclosed nor would have suggested such semiconductor device as in the present claims, having the copper film interconnect, neighboring film and dielectric film, particularly positioned relative to each other, as in the present

claims, and with the copper film interconnect having a multilayered structure including a copper film as formed through sputtering and a copper film as formed through plating or chemical vapor deposition (see claim 3); or wherein at least one of the copper film and the neighboring film is a film made by physical vapor deposition (see claims 30 and 36).

The present invention is directed to a semiconductor device having a layered (for example, multilayered) interconnect structure. In recent large-scale-integrated semiconductor devices, copper interconnects are being employed since they have a lower electrical resistance than conventional aluminum interconnects. However, diffusion of copper in semiconductor devices, e.g., into dielectric films thereof, degrades characteristics of such devices; and, accordingly, diffusion barriers of, for example, titanium nitride, tungsten or tantalum have been used.

However, in large-scale-integrated semiconductor devices with fine patterns, in which high-density current occurs, electromigration (in which atoms are diffused owing to electron streams flowing in the fine patterns and due to heat generated by the flow of electrons) is a problem, causing voids and interconnect breakdowns. Use of a diffusion barrier of, e.g., titanium nitride, does not provide satisfactory electromigration resistance.

Against this background, Applicants have clarified a source of the electromigration problem, and having clarified such source, have found a

technique which overcomes the problem of voids due to electromigration and the resulting interconnect breakdown. Applicants have clarified that, in a layered interconnect structure using, for example, a titanium nitride film as a diffusion barrier kept in contact with the copper film, the significant difference between the material of the diffusion barrier and copper in the length of the sides of the unit cell brings about a disordered atomic configuration at the interface therebetween, thereby promoting copper diffusion that results in the problem of voids and interconnect breakdowns. Having clarified this problem, and in order to prevent the voids and breakdowns in copper interconnects, Applicants utilize materials that differ little from copper in a length of the sides of the unit cell. See the paragraph bridging pages 2 and 3 of Applicants' specification. Applicants have further found that where the difference between sides of the rectangular unit cells representing the copper and neighboring films is less than 13%, the aforementioned problems in voids and interconnect breakdowns are avoided.

In addition, Applicants have found specific materials, and also specific techniques for forming the various layers, whereby the aforementioned differential in lengths of sides of the units cells are sufficiently small, so as to avoid the voids and interconnect breakdowns. That is, Applicants have found that by forming at least one of the adjacent layers of copper and neighboring film by physical vapor deposition, with selection of material of the neighboring film,

the aforementioned problem of voids can be avoided, due to the structure formed.

Attention is respectfully directed to Figs. 2-5 of Applicants' original disclosure, together with the description on pages 13-16 of Applicants' specification. This shows that the diffusion coefficient of the copper film greatly increases in regions where there is a great size differential. It is respectfully submitted that this evidence in Applicants' specification must be considered, in determining the question of unobviousness. See In re DeBlauwe, 222 USPQ 191 (CAFC 1984). It is respectfully submitted that this evidence shows unexpectedly lower diffusion occurs in connection with copper or platinum, on the one hand, and the various materials within the present claims, including ruthenium, on the other, where the difference in unit cell length is relatively small. This evidence shows unexpectedly better results achieved according to the present invention, and clearly establishes unobviousness of the present invention.

It is emphasized that in claims 3, 30 and 36, the neighboring film is provided interposed between the copper interconnect and a dielectric film. It is respectfully submitted that a neighboring film between the copper and this dielectric film is different from, e.g., the use of barrier materials as disclosed in the IBM Technical Disclosure Bulletin article preventing copper diffusion into silicon (a semiconductor). As will be shown in the following, it is respectfully

submitted that the references as applied by the Examiner do not disclose, nor would have suggested, material including, for example, ruthenium, for avoiding electromigration of copper into a dielectric film; and, accordingly, would have neither disclosed nor would have suggested the present invention.

Hussein, et al. discloses fabrication of via plugs and metal lines in interconnect systems, including use of a barrier layer formed onto a surface of a substrate that has at least one via, with a conductive layer formed on the barrier layer. A photoresist layer is formed on the conductive layer and patterned, with a metal via plug being formed onto the at least one via. A metal line is formed on the metal via plug, the layer of photoresist is removed, and the conductive layer not covered by the metal line is removed. See column 2, lines 14-22. This patent discloses use of appropriate conductive layers for the barrier layer 5, which may be titanium nitride or tantalum, and is provided to prevent a metal line 11 that is later deposited in each via 4, from diffusing into the underlying and adjacent dielectric layer 3. Note column 3, lines 9-11, 18 and 19, and 55-58.

It is emphasized that Hussein, et al. discloses, that, where a conductive material is used for the barrier layer, titanium nitride or tantalum, to prevent diffusion into the underlying and adjacent dielectric layer, is used. Such disclosure as in Hussein, et al. would have neither disclosed nor would have suggested the presently claimed subject matter, including, in particular, wherein one of the specified materials for the neighboring film (e.g., ruthenium) as in

claims 3, 30 and 36, is positioned between the dielectric film and the copper film interconnect.

It is respectfully submitted that the secondary reference as applied by the Examiner would not have rectified the deficiencies of Hussein, et al., such that the presently claimed invention as a whole would have been obvious to one of ordinary skill in the art.

The IBM Technical Disclosure Bulletin article discloses a diffusion barrier between copper and silicon. This patent discloses that a metal ideally fulfilling criteria for such diffusion barrier between copper and silicon is rhenium, and that similar desirable values of elastic constant and eutectic temperature or a property of osmium, ruthenium and iridium as well.

It is respectfully noted that the IBM Technical Disclosure Bulletin article discloses a diffusion barrier between copper and silicon. In contrast, Hussein, et al. discloses a barrier layer between a metal line, e.g., of copper and an underlying and adjacent dielectric layer. It is respectfully submitted that one of ordinary skill in the art concerned with in Hussein, et al., looking to avoid diffusion of, e.g., copper into a dielectric layer, would not have looked to the teachings of the IBM Technical Disclosure Bulletin article, having a diffusion barrier between copper and silicon.

In this regard, it is respectfully submitted that the Examiner has pointed to no proper motivation for using the teachings of the IBM Technical Disclosure

Bulletin article, of a diffusion barrier between copper and silicon, as a barrier layer in Hussein, et al. In this regard, it is respectfully submitted that, from the teachings of the prior art references, one would not have known (for example, one would have not have had any predictable degree of success) as to whether a barrier material to prevent diffusion into silicon would have a same effect for preventing diffusion into another film (e.g., a dielectric film). Thus, it is respectfully submitted that it is improper to combine the teachings of the applied references, under the guidelines of 35 USC 103; and that, in any event, the combined teachings of the applied references would have neither disclosed nor would have suggested the neighboring film of, e.g., ruthenium, between the copper film interconnect and dielectric film, as in the present claims.

The contention by the Examiner that Hussein, et al. recognizes that copper diffusion into silicon and, also, into any surrounding dielectric material, can result in defective circuitry, is respectfully traversed. It is respectfully submitted that Hussein, et al., at column 1, lines 55-57, describes copper diffusion into a dielectric layer, not into silicon. It is respectfully submitted that Hussein, et al. does not disclose, nor would have suggested, any equivalency of the problem of copper diffusion into silicon and into a dielectric layer, or equivalent solutions, and would not by itself or with the teachings of the IBM Technical Disclosure Bulletin article have provided any motivation for combining the teachings of Hussein, et al. and of the IBM Technical Disclosure Bulletin article.

Attention is also respectfully directed to column 1, lines 55-57; column 1, lines 58-60; and column 3, lines 9-13, of Hussein, et al. Such disclosures refer to diffusion of copper into the underlying and adjacent dielectric layer. Clearly, and contrary to the interpretation of Hussein, et al. by the Examiner, this document is concerned with copper diffusion into a dielectric layer; and provides no basis for motivation of utilizing, e.g., ruthenium for the neighboring film between the copper film interconnect and dielectric film, as in the present claims 3, 30 and 36.

The further contention by the Examiner that the IBM Technical Disclosure Bulletin article teaches that, inter alia, ruthenium is an excellent barrier against the diffusion of copper is noted. It is respectfully submitted that this article discloses various materials, including ruthenium, as barriers against the diffusion of copper into silicon; it is respectfully submitted that this article provides no disclosure as to the use of the listed materials as a barrier against diffusion of copper into a dielectric film.

In view of the foregoing comments and amendments to the claims, reconsideration and withdrawal of the finality of the Office Action mailed December 3, 2001, and entry of the present amendments as a matter of right, and reconsideration and allowance of all claims remaining in the application, including claims 3, 30 and 36, are respectfully requested.

In any event, entry of the present amendments, and reconsideration and allowance of all claims in the application, including claims 3, 30 and 36, are respectfully requested.

Attached hereto is a marked-up version of the changes made to the claims by the current Amendment. This marked-up version is on the attached pages, the first page of which is captioned "VERSION WITH MARKINGS TO SHOW CHANGES MADE".

To the extent necessary, Applicants petition for an extension of time under 37 CFR 1.136. Please charge any shortage in fees due in connection with the filing of this paper, including extension of time fees, to the Deposit Account No. 01-2135 (Case No. 501.36931X00) and please credit any excess fees to such Deposit Account.

Respectfully submitted,

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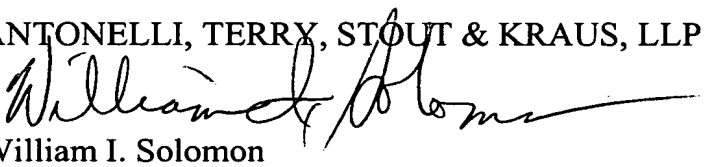

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VERSION WITH MARKINGS TO SHOW CHANGES MADE IN THE CLAIMS

Please amend the claims presently in the application as follows:

3. (Twice Amended) A semiconductor device with a multilayered structure comprising a copper film interconnect formed on one primary surface of a semiconductor substrate, [and] a neighboring film formed in contact with said copper film interconnect, and a dielectric film positioned such that the neighboring film is between the dielectric film and the copper film interconnect, wherein said neighboring film is formed of ruthenium as the primary constituent element, and is formed through sputtering, and said copper film interconnect has a multilayered structure comprising a copper film as formed through sputtering and a copper film as formed through plating or chemical vapor deposition.

6. (Thrice Amended) A semiconductor device with a structure comprising a copper film interconnect formed on one primary surface of a semiconductor substrate, a neighboring film formed in contact with said copper film interconnect, a plug formed in contact with said neighboring film, and a diffusion barrier formed in contact with said plug and said neighboring film, wherein said neighboring film includes a ruthenium film, said plug is formed of a ruthenium film, said diffusion barrier is formed of a titanium nitride film, and at least one of said copper film interconnect and said neighboring film is a film formed through sputtering, wherein the neighboring film and the plug substantially prevent voids due to electromigration of the copper or platinum of the copper or platinum film.

30. (Amended) A semiconductor device having a layered interconnection structure including a copper film formed overlying a surface of a semiconductor substrate, and having a dielectric film overlying the surface of the semiconductor substrate, wherein the layered interconnection structure includes the copper film and a neighboring film adjacent the copper film, the neighboring film containing a material selected from a group consisting of rhodium, ruthenium, iridium, osmium and platinum as the primary constituent element, at least one of (a) the copper film and (b) the neighboring film being a film made

by physical vapor deposition, and wherein the dielectric film is positioned such that the neighboring film is between the cupper film and the dielectric film.

36. (Amended) A semiconductor device having a layered interconnection structure including a copper film overlying a surface of a semiconductor substrate, and having a dielectric film overlying the surface of the semiconductor substrate, wherein the layered interconnection structure includes the copper film and a neighboring film located at at least one of (a) overlying the copper film and (b) between the copper film and the substrate, the neighboring film including a material selected from a group consisting of rhodium, ruthenium, iridium, osmium and platinum as the primary constituent element, at least one of (a) the copper film and (b) the neighboring film being a film made by physical vapor deposition, and wherein the dielectric film is positioned such that the neighboring film is between the copper film and the dielectric film.

37. (Amended) A semiconductor device having a layered interconnection structure including a copper film or a platinum film formed overlying a surface of a semiconductor substrate, wherein the layered interconnection structure includes the copper film or the platinum film, and a neighboring film located at at least one of (a) overlying the copper film or the

platinum film and (b) between the copper film or the platinum film and the substrate, the neighboring film including an element selected from a first group consisting of rhodium, ruthenium, iridium, osmium and platinum when the layered interconnection structure includes the copper film and the neighboring film including an element selected from a group consisting of rhodium, ruthenium, iridium and osmium when the layered interconnection structure includes the platinum film, at least one of (a) the copper film or platinum film and (b) the neighboring film being a film made by physical vapor deposition, wherein the neighboring film substantially prevents voids due to electromigration of platinum when the layered interconnection includes the platinum film and the neighboring film substantially prevents voids due to electromigration of copper when the layered interconnection includes the copper film.